PHOTODISINTEGRATION OF DEUTERIUM BY TWENTY MEV X-RAYS

BY

EVERETT GLADDING FULLER

B.A., Amherst College, 1942
A.M., University of Illinois, 1947

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN PHYSICS
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1950

URBANA, ILLINOIS

1950

Digitized by the Internet Archive
in 2026

https://archive.org/details/IA41549807_0080

PHOTODISINTEGRATION OF DEUTERIUM BY TWENTY MEV X-RAYS

BY

EVERETT GLADDING FULLER

B.A., Amherst College, 1942
A.M., University of Illinois, 1947

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN PHYSICS
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1950

URBANA, ILLINOIS

1950

ACKNOWLEDGMENTS

The author wishes to gratefully acknowledge the encouragement and advise of Professor A. O. Hanson who initiated and directed this work. He also wishes to acknowledge the helpful discussions of the work held with Professor S. M. Dancoff and Mr. J. S. Blair. The calculations performed by Mr. Blair and the many long discussions held with him have been particularly helpful.

The task of lining up the collimator and making the exposures was accomplished with the able assistance of Mr. B. C. Diven and Mr. D. Riesen.

The analysis of the low energy plates was greatly facilitated by the careful and accurate work of Wilna D. Johnston who helped in the reading of these plates and the analysis of the data.

This work was assisted by the joint program of the ONR and AEC.

R. UNIV. BIBLIOTHEEK LEIDEN

PHOTODISINTEGRATION OF DEUTERIUM BY TWENTY MEV X-RAYS

A study was made of the angular distributions and the distribution in energy of the photoprotons arising from the photodisintegration of deuterium by the continuous x-ray spectrum produced when electrons accelerated in the betatron to a kinetic energy of 20.3 Mev impinged on a .005″ Pt target. The x-rays were collimated into a beam having a full angular width of thirty-six minutes of arc by means of a laminated lead collimator placed between the coil boxes of the betatron. The collimated x-ray beam passed through the .003″ Al entrance and exit windows of a reaction chamber filled with deuterium gas. Ilford, type C-2, one hundred micron nuclear emulsions were placed inside the reaction chamber to one side of the x-ray beam to detect the protons resulting from the photodisintegration of the deuterium gas in the beam. Plates were exposed with the chamber filled with three atmospheres of deuterium to emphasize the high energy end of the spectrum, with one atmosphere to emphasize the low energy end, and with one and three atmospheres of hydrogen.

The energy of each proton track as it entered the plate was determined from its measured range corrected for the verticle shrinkage of the emulsion and the range-energy relation for the Ilford emulsions.[1] These energies were then corrected for the range of each track in the gas of the chamber before it reached the emulsion. From the known geometry of the plates with respect to the x-ray beam and the angular measurements made on each track it was possible to determine the angle each track made with respect to the direction of the incident quanta. Angles could be determined between 20 and 160 degrees in the laboratory system. The quantum energy corresponding to each track was determined from the measured angle and energy of each track in the laboratory system.

There was a background due to the neutron flux through the chamber. On the basis of a survey made of the recoil

protons produced in n-p scattering events which took place both within the emulsion itself and in the hydrogen filled chamber it was concluded that the principle background effect would be due to the n-d scattering taking place within the deuterium gas filling the chamber. The correction for this background was made by converting the n-p scattering observed on the plates exposed with the chamber filled with hydrogen to expected distributions for the case of n-d scattering. The background corrections were important only for the low energies. For photons above 8 Mev the correction was negligible.

Differential cross section curves in the center of mass system were obtained corresponding to mean photon energies of 5,7,9,11,13.3 and 17 Mev. In each case except for the highest energy interval the distributions are fitted by the corresponding Rose-Goertzel[2] expression for the charge transitions, i.e. in their notation: $A_0(\mu) \sim (L/\zeta^4)^2 \sin^2\theta$. For the highest energy interval an isotropic component of 0.15 is included. There is definite evidence for such a component although its magnitude is in considerable doubt since values anywhere between 0.1 and 0.3 fit the data equally as well. Within the large experimental errors this value is in agreement with the preliminary results of Wäffler and Younis[5] who obtained $0.05 \pm .15$ for the isotropic component in this energy range.

The calculations of Rose and Goertzel were made for photons having energies greater than 50 Mev. The forward asymmetry predicted by their calculations of the angular distribution seems to be definitely present in the distributions for the relatively low energies used in this experiment. This is in agreement with the calculations of Guth and Marshall[3] and of Blair[4] who calculate the asymmetry on the basis of the interference between the electric dipole and the electric quadripole transitions. At these energies the Rose-Goertzel expression gives an angular distribution which differs only slightly from that given by an expression of the form:

$$\sigma(\theta)\,d\Omega \sim \sin^2\theta(1 + c\cos\theta)\,d\Omega$$

For the highest energy interval the value of "c" determined from the experimental data is $0.4 \pm .1$. Within the experimental error, this is in agreement with the value of 0.32 obtained by an expansion of the Rose-Goertzel expression or the value of 0.3 calculated by Blair for 18 Mev photons.

Using the photon spectrum for thin target betatron radiation determined by Koch and Carter[6] a curve was obtained for the relative cross section for the photodisintegration of deuterium as a function of photon energy. This curve falls off slower than does the Bethe-Peierls expression. If a curve having the energy dependence of the Bethe-Peierls expression is matched to the experimental curve at 6 Mev the experimental curve would have to be lowered by 28 percent at 17 Mev to bring it into agreement with the Bethe-Peierls curve. On the basis of the statistical errors in the photoproton curve and the photon spectrum and the possible systematic errors in the energy scales it is possible to just account for this discrepancy. These data, while allowing a cross section that falls off as fast as the Bethe-Peierls expression, would not be compatible with a cross section falling off more rapidly with increasing photon energy than does the Bethe-Peierls expression.

BIBLIOGRAPHY

1. C. M. G. Lattes, P. H. Fowler and P. Cuer, Proc. Phys. Soc. London, 59, 883 (1947).

2. M. E. Rose and G. Goertzel, Phys. Rev. 72, 749 (1947).

3. Work of E. Guth and J. J. Marshall to be published. The author wishes to express his gratitude for being sent these results before publication of the work.

4. Unpublished work of J. S. Blair.

5. H. Wäffler and S. Younis, Helvetica Physica Acta 22, 414 (1949).

6. H. W. Koch and R. E. Carter, Phys. Rev. 75, 1950 (1949).

VITA

Everett Gladding Fuller was born in Springfield, Massachusetts on December 6, 1920. He started his public school training in that city but completed it in the public schools of Woodbury, New Jersey to which city his family moved in 1930. He was graduated from Woodbury High School in 1938. He received his BA degree from Amherst College in 1942 where he majored in Physics.

From July 1942 to April 1946 he was in the Armed Services. He was graduated from the AAF Meteorological School at the University of Chicago in May 1943. He then served for two years as a Weather Officer assigned to the Tenth Weather Squadron in the CBI Theater.

In March 1946 he entered the University of Illinois as a graduate student in Physics. He received his AM degree from that university in 1947.

From August 1946 to February 1948 he was a teaching assistant in the Department of Physics of the University of Illinois. From February 1948 until the present he has been a research assistant.

He has published a preliminary report of the present work entitled, "Photodisintegration of Deuterium by Seven to Twenty Mev X-Rays" (Phys. Rev. 76, 576 (1949)).

He is an associate member of Sigma Xi (Illinois).

He is a member of the American Physical Society and the American Meteorological Society.